Textile Logics in a Digital Architecture

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Abstract. This paper questions the representational logics of a new class of digital-material practices incorporating material performance. Presenting the concept of ‘textile logic’, the paper discusses how computational design tools that allow for a parametrisation of material behaviour are foregrounding the examination of structural principles that lie outside traditional compressive logic. By pointing to the structural thinking of Vladimir Shukhov, Buckminster Fuller and Robert Le Ricolais, as well as contemporary practitioners such as Cecil Balmond and Peter Testa the paper examines the precedents for incorporating tensile self-bracing as a structural principle and how textiles can become a model for architectural design. The paper presents the research by design enquiry ‘Shadow Play’ examining the involved traditions, methods and material practices of textile design and the here embedded systems of material specification can be advantageously ported to digital design.

Keywords. Digital design practice; textiles; structural design; material behaviour.

INTRODUCTION

Recent research presents a new conceptualisation of feedback in the design chain (Menges 2010, Tamke 2011, Deleuran 2011). Investigating ways of integrating material performance as a design parameter, these projects employ the ability to model force and flow in order to parametrise and calculate material properties. By understanding materials not as static or inanimate, but as engaged by complex behaviours, a new dimension of design potentials have been unleashed (Suare 2008). This is leading to the emergence of a new digital-material practice in which the design and detailing of materials are directly linked to the design and detailing of buildings. Aiming to innovate structural thinking and create better and more sustainable material usage (Knippers 2011), these new material practices rely on the ability to compute and specify complex structural systems in which networks of members pass forces between them. However, whereas the shared digital platform between design, simulation and fabrication allow us to interface information between the practices of analysis and design, we need better means of representing material behaviour in meaningful ways so as to actively incorporate material understanding into our designs.

This paper presents an interdisciplinary research enquiry into the application of concepts and tools from the field of textile design within the field of digital design practice. Textile design presents interesting models of thinking structures that rely on the flexibility, tension and bend of materials. As a tradition it has developed means for describing textile structures in ways that omit explicit geometric descriptions of shape and size and instead focuses...
on material connectivity and structural integrity. By understanding representation in textile design and defining the term ‘textile logic’ it is this paper’s aim to provide new models by which to describe complex bending active structures characterised by multiple stranded circular interdependencies. The paper presents the research probe “Shadow Play” examining the textile logics of material assembly within structural systems based on redundancy and devising a new representational logic.

TEXTILES AS STRUCTURAL MODEL
Textile logics suggest an architectural thinking of textile membranes as alternatives to traditional structural hierarchies. Textiles are interesting structural models as they are strong, lightweight, adaptable and give designers great formal freedom. Contemporary research practice have invented concepts such as “macro-weaving” (Simmonds 2006, Ramsgard Thomsen 2011), “interbraiding” (Weinand 2011) and “large-scale lacing” [1]. The aim for these structural investigations is to understand how principles of friction and self-bracing can employ internal-compressive forces to gain stiffness and thereby structural integrity. These experimental studies are radically different to the traditional hierarchical thinking of compressive structures in which few members are optimised to transfer force linearly through the structure, instead relying on a complex interdependent circularity between many parallel members. As explored by Beesley and Hanna in their text “Lighter: a transformed architecture”, textiles in architecture provides a new model by which the rigid orders of primary, secondary and tertiary structures are replaced by interdependent structures that perform together: “Instead of fixed, rigid connections based on compression, textile structures use tension. The binding of one fibre to the next is achieved through the tension exerted by the immediately adjacent fibres. Rather than relying on support from the previous, stronger member, the system is circular, holding itself in exquisite balance” (Beesley and Hanna 2005).

This emerging research field takes precedence in the works of the Russian engineer Vladimir Shukhov developed light metal lattice structures as radio- and water towers (Graefe 1990). These structures diagonally spin thin metal slats into hyperboloid drums pushed out by horizontal circular members. Each crossing of slats is connected thereby creating stiffness. The structures are essentially self-bracing, pressing themselves into tension. A second class of load distributing networks is the gridshell. Shukhov’s early steel gridshell roofs for projects such as the pumping station in Groznyj or the ‘All Russian Exhibition’ in Niznij Novgorod in 1895 developed the technique using steel slats (Graefe 1990). Here, each member is fixed against each other in a lattice work creating stiffness. In the roof for the Vyksa steelworks, Shukhov furthered complicated the shaping of the gridshell by using a curved beam to rest the slats on. This curvature creates a corresponding bulge in the longitudinal direction thereby creating a double curvature in the shell. But it was Frei Otto who in the 1970’s fully explored the geometric freedom of gridshell structures. In the Multihalle Mannheim project the flexible nature of gridshell was developed (Nerdinger 2005). Using timber the free-form structure was initially built on the ground as lattice based layering of wood slats connected by intersecting nodes. The structure was then raised into

Figure 1
Shadow Play installation at House of Architecture, Copenhagen.
position after which each node was fixed. The Multihalle Mannheim exploits the compressive nature of the structural system. As the structure is raised the nodes in effect slide upon each other allowing the free form to be shaped.

During the late 1940’s and 50’s the work of Buckminster Fuller and Robert Le Ricolais further articulated the interdependence between tensile and compressive members. Working with tension rather than friction, both experimented with structures in which compressive members are pulled apart by tensile cables. In Le Ricolais’ work rigid rings are held in place by networks of cables creating hyperboloid tubular constructions. Le Ricolais conceived these tensile networks as auto-morphic beams. In Fuller’s work the synergetic relationship between tension cable and compressive strut is conceived as clearly differentiate tension-compression structures. In these tensional integrities, or tensigrities, the compressive members are held together by tensile cables (Gorman 2005).

If textiles can be understood a network of connections distributing stress synergetically across its surface a key question becomes what principles of organisation are appropriate for surfaces that perform at architectural scale. It is this tradition of structural thinking that has informed the practice of a contemporary generation of research-practitioners such as Cecil Balmond and Peter Testa. At present the field is limited by the lack of tools for understanding, analysing and simulating these force-relations. By examining the possibility of creating complex computational models that can calculate and digitally prototype these textile-based systems of material organisation, they suggest an emerging rupture in the thinking of architectural representation.

This question informs the contemporary work of engineer Cecil Balmond (Simmonds 2006). Working across a series of projects, Balmond has explored the structural principles of weave. Inventing the idea of macro-weaving, Balmond develops strategies by which the woven network’s mutual friction based stiffening can be exploited for architectural application. Developing the work, Balmond points to a series of limitations. Where weaving as a technique necessitates flexibility of each fibre, these simultaneously need to be stiff enough to withstand bending or buckling. A second point is the relative difference between the scale of the surface and that of the individual fibre. Pointing out the difference between the yarn lengths used in traditional fabrics and the given scales of building materials, Balmond returns to the structural principles of reciprocal truss frameworks to further continue the work with ‘woven’ structures while at the same time engaging with the practical limitations of the building process. In projects such as the Shigeru Ban’s ‘Forrest Park Pavillion’ proposal and the realised Alvaro Siza Serpentine Pavilion, a network of single elements, the size of two units in the weave, create a reciprocal grid in which each member leans upon the next. Controlling the shape and length of each individual member computationally, the structures are given geometrical freedom.

In the speculative work of Peter Testa and Devyn Weiser the question of the length of each member is given primacy. In projects such as ‘Weaver’, ‘Carbon Tower’ and ‘Extreme Networks’, the imagination of endlessly long carbon fibre strands is used to examine the making of complex structural surfaces (Testa 2007). Where the ‘Carbon Tower’ investigates the computational modelling of weave structures, ‘Extreme Networks’ suggests non-woven structures as a principle for complex non-hierarchical surfaces. Non-woven fabrics, like felt, are randomly entangled creating unordered structures where discreet elements compound to create a friction based surface. Where traditional felts depend upon the given lengths of wool fibres, new synthetic non-woven uses long fibres to enhance the connectivity of the surface. In Testa and Weiser’s vision these complex networks are computationally driven. Moving away from a reductionist logic of networks as connections between shortest paths, their work explores agent based systems to drive each strand within the surface as a trajectory of movement. Suggesting the term agential materialist combinatorics the pro-
ject fuses computational logics with material ones (Burke 2007).

TEXTILE LOGICS AS REPRESENTATIONAL LOGIC: PATTERN AS CODE

Testa and Weiser’s work point to the challenges that working for and with a textile logics present to the traditions of material description. Where the orthogonal logics of the section and the plan, ported into the Cartesian dimensions of the 3D model, pre-empt the structural logics of compression, we need new descriptions in order to fully anticipate and analyse the complex circularity of textile-based structures.

Where Testa and Weiser’s work result in geometric representations, the underlying computational logics relies on the relations of the individual agents. As such they are conceptualised in much the same way as a textile pattern such as a weave or knitting patterns. Textile patterns are interesting models for reflecting on how architectural representational logics could perform Operating outside the geometric space of measured extension textile patterns, such as weaving, knitting or lacing patterns are purely diagrammatic existing as a material code clarifying the logics of assembly and therefore the material-structural integrity of the resulting fabric.

In weave the traditional “draft” diagram consisting of the “threading”, the “tie-up”, and the “treadling” presenting the interlacement of the (vertical) warp threads with the (horizontal) weft threads [4]. These diagrams are ascalar and give no indication of how the resulting textile will look, but exist instead as instructions for fabrication. As such they are interesting models for considering architectural descriptions that incorporate with material behaviour and result in instructions for fabrication. As a model of simplification these diagrams exclude geometric depiction as these are too complex and information-heavy to read. As architectural practice continues to explore the potential of working with complex textile-based structure how can we devise hybrid descriptions that enable us to visualise and creatively form these systems? How could the invention of hybrid drawings combining textile diagrams with geometric information allow an interfacing with existing building practice, with the extended partnership of building design (analysis, simulation and fabrication) and with the extended material complexity of buildings that need multiple materials to account for weather proofing, insulation and programme?

SHADOW PLAY: A CASE STUDY

The paper presents the installation “Shadow Play”. Developed for the exhibition “Transformative Textiles” at the Architecture House in Copenhagen, the installation examines the forming of parametrically

Figure 2
Weave, knit and lace patterns. Weaving patterns present the relation between the warp and weft in a diagrammatic form shown in the tie-up, treadling and draft diagramme. In knitting and lacing the patterns diagram the implementation of different stitch types. Patterns after Sally Orgren [1], Monika Fahrnberger [2] and Bridget Cook (11).
encoded material descriptions. The installation is understood as a screen filtering the light creating a dynamic shadow play across the entrance space of the Architecture House. Using 0,6 mm pine wood veneer as a base material for the structure the installation makes use of the potential for bending. Building on prior research into textile-based structural systems (Ramsgard Thomsen 2011, Ayres 2012), the design project examines ways of encoding and describing material behaviour for architectural scale structures.

THE TEXTILE STRUCTURE

In “Shadow Play” the material system is organised as a series of interconnected loops. Each loop stitch binds two members together and passes the fibres forward in the structural weave. The installation is tied in a three dimensional weave system. Using copper ties, each member is interconnected in a series of looping stitches that gather the material and interconnect in three dimensions. At the outset of the design project we explored different systems of interconnectivity that could engage the material behaviour of bending while creating a integrated structure.

The designed system is based on a two dimensional frame on to which each member is hung. This ‘warp frame’ of individual fibres is then connected diagonally downwards in double loops. At each vertical stitch level the direction of the diagonal is swapped resulting in an integrated three dimensional textile structure.

In the structure each member is inherently weak, and it is only through the designed system of assembly and interconnecting looping that the structural whole is given stiffness and strength. To design the system we used simple parametric design tools incorporating a empirical evaluation of the performance of the pine veneer. The 3D model draws the relationships between each member allowing for mapping of the looping. The model exists as a programmed design space in which the shadow space of the installation can be tested and designed.
The design model is interfaced with a second tier fabrication model in which the lengths of each member and the position of the loops are detailed. Both representations are purely relational outlining the coordinates of the material assembly and the project relies on physical prototyping to understand the resulting form. In Shadow Play the veneer wood is manually cut into strips of varying breadth. Varying along the depth of the installation the individual members are thinner the closer they are to the window allowing for an intensification of light play. Each member passes through the length of the installa-
The installation is designed to allow people to pass under the structure and the member length is accordingly varied from 2-10 meters.

CONCLUSION
In Shadow Play the parametric design model is developed to incorporate an empirically defined understanding of the bending of the veneer wood. The model is designed to allow for direct feedback between designer and the embedded modelling of material behaviour allowing an understanding of the minimum and maximum of bending. The model hybridises a textile design led understanding of the role of representation with traditional architectural projection. On the one hand the mode exists as a three dimensional representation outlining the size and shape of the structure and allowing the evaluation of the design proposition while on the other hand the model diagrammises the material connectivity of the three dimensional weave structure. The model is as such both directly architectural as well as a tool for understanding material composition in the installation.

CREDITS
The Shadow Play installation was developed as part of the Architectural Textiles exhibition, shown at the Architecture House, March-June 2012, Copenhagen. The project was funded by the Nordic Culture Fund, 2011-12.

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